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RESEARCH ARTICLE

Medium- and large-sized mammals in forest remnants of the southern Cerrado: diversity and ecology

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Abstract

Here we present a complete data set on the richness of medium- and large- sized mammals from a fragmented area of the southern Brazilian savanna (Cerrado). We described the frequency, occurrence status and activity period of the most common species. In each remnant, the community of medium- and large-sized mammals was inventoried across the following methods: tracks/prints, vocalizations, sightings, burrows, and camera trap images between August 2016 and January 2017. We recorded 23 species of medium- and large-sized mammals, of which seven are threatened. The study area presented a great potential, where we recorded 45.1% of all medium- and large-sized mammal species occurring in the Cerrado. *Myrmecophaga tridactyla*, *Dasypus novemcinctus*, *Tapirus terrestris*, *Cerdocyon thous* and *Cuniculus paca* were classified as common, which was expected since they have large habitat range, and therefore, can be recorded more frequently. Species with large body size, such as *T. terrestris, M. tridactyla* and *C. thous,* were also the ones with the greatest variation in time period of activity, occurring both in nocturnal and diurnal time periods. Therefore, our study underscores that this transition area, although fragmented, still maintains an expressive fauna of medium- and large-sized mammals, including endangered species.

Keywords

Endangered species, frequency, inventory, *Puma yagouaroundi*

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Introduction

There are about 6,399 mammal species, 701 of which are distributed in Brazil and of which 194 can be considered medium- and large-sized (Paglia *et al.* 2012; Burgin *et al.* 2018). Due to recurring threats to the remaining populations, most mammal species, especially those of medium and large size, are under risk of extinction in Brazil (*e.g.,* Grelle *et al.* 2006). Previous empirical works have demonstrated that medium- and large-sized mammals are specifically sensitive to the effects of fragmentation (Chiarello, 1999; Calaça *et al.* 2010; Magioli *et al.* 2016) and changes in the landscape configuration (Garmendia *et al.* 2013). Such threats affect medium and large sized mammals primarily due to the characteristics of this group, such as low population density (Grelle *et al.* 1999), small litter size and long gestation period (Brown 1995), and body size (Forero-Medina *et al.* 2009). In addition, behavioral characteristics such as activity patterns can be influenced by fragmentation processes (Norris *et al.* 2010). However, although studies on the consequences of population fragmentation for these mammals are common in the literature (*e.g.* Calaça *et al.* 2010; Magioli *et al.* 2015), effective actions for species conservation depend on more basic information related to species distribution, diversity and behavioral responses to changes in habitat (e.g. fragmentation process) (Norris *et al.* 2010; Hortal *et al.* 2015). For instance, in ecotone areas such as the southern Brazilian savanna (Cerrado biome), this basic information is still incomplete. In fact, the inconsistencies in survey efforts and basic information may result in high spatial variation in the quality and reliability of the data available for biodiversity research (Gaston & Rodrigues, 2003; Mace, 2004; Hortal *et al.* 2015), which is particularly serious for threatened ecosystems, such as the Cerrado.

The Cerrado, besides being the second largest Brazilian biome, is considered one of the world's most biodiverse hotspots due to its high species richness and endemism, in addition to anthropic threats (Myers *et al.* 2000; Klink & Machado, 2005). It holds a high diversity of medium- and large-sized mammals, with 56 species distributed in the following orders: Artiodactyla, Carnivora, Cingulata, Lagomorpha, Perissodactyla, Pilosa, Primates and Rodentia (Paglia *et al.* 2012). Also, the biome connects and borders adjacent to all other Brazilian biomes – Amazonian, Atlantic Forest, Pantanal and Caatinga (Ratter *et al.* 1997). The southern portion of the Cerrado, in the state of Goiás, has a history of high landscape fragmentation due to sugar cane monoculture and livestock herding, causing drastic changes in landscape connectivity (Rossi, 2016). Consequently, few studies have documented the diversity and ecology of mammals for this region (see Hannibal *et al.* 2015a). Such studies were mainly based on images from camera traps. Thus, there is incomplete and biased data on the distribution of medium- and large-sized mammals in highly impacted regions of the Cerrado. Considering this context and the fact that a biodiversity inventory is the first step for major decision-making processes and for development of long-term conservation implementations, we present herein a complete data set for the richness of medium- and large-sized mammals in a region of the southern Cerrado. In addition, we describe the occurrence status based on species frequency, and the activity period for the most common species.

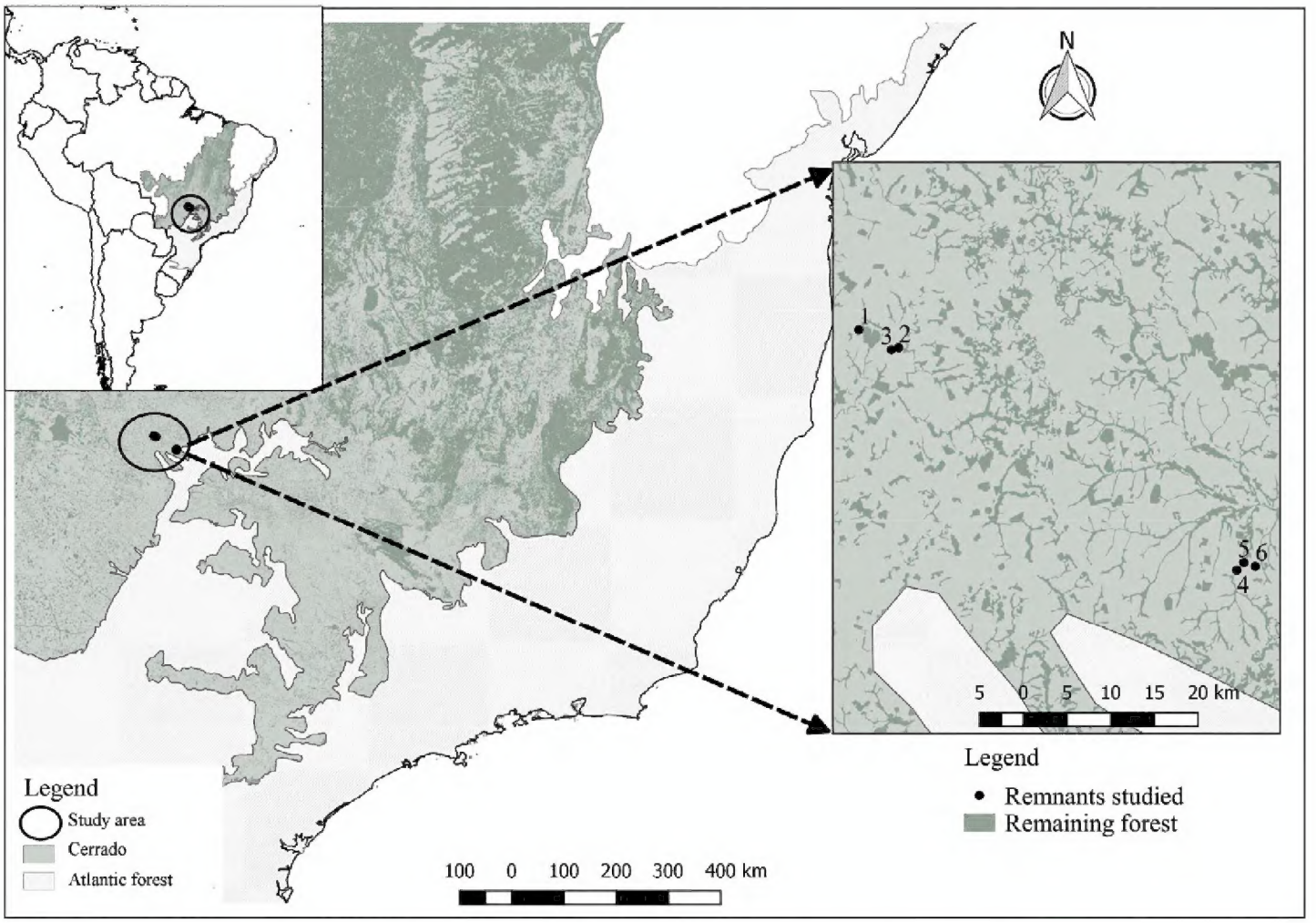

Figure 1. Distribution of the six sampled remnants in the southern Cerrado, Brazil.

Methods

Study area

Located in the southern Cerrado, in central Brazil (Figure 1), this region has undergone intense anthropic activity (*e.g.*, farming and ranching), which has caused fragmentation and a great loss of habitat. In this fragmented landscape, we selected six remnants for sampling (Table 1, Figure 1), three of which were entirely inserted in the Cerrado domain and the other three in the transition zone between the Cerrado and the Atlantic Forest. The remnants range between 1.5 and 427.52 ha, and are composed of different physiognomies, such as woodland savanna, semi-deciduous forest, riparian forest and Cerrado wetlands – veredas (Table 1). The climate is Aw (Koppen), with a dry season from April to September and a wet season from October to March (Alvares *et al.* 2014). Elevation varies from 500 to 640m.

Data collection

Medium- and large- sized mammals were defined as those over 1kg in body mass (Chiarello, 2000). In each remnant, the community of medium- and large-sized mammals was inventoried across the following methods: tracks, vocalization, direct sightings, burrows, and camera trap photography between August, 2016 and Janu-

Table 1. Data for the sampled remnants, including area of the remnants (ha) and sampling effort for the camera trap and active search by remnant, for six patches from southern Cerrado, Brazil. Physiognomy type: rf: riparian forest, sf: semi-deciduous forest, ve: vereda, ws: woodland savanna.

Remnants	Lat	Long	Physiognomy	Area(ha)	Sample effort	
					Camera Trap (H)	Active Search (km)
1	18°14'S	51°10'W	ws	427.52	5.760	6
2	18°15'S	51°8'4W	ws, rf	13.64	2.880	2.6
3	18°15'S	51°9'W	ws	1.5	2.880	1.2
4	18°29'S	50°46'W	rf, ve	28.33	2.880	3.6
5	18°28'S	50°46'W	rf, sf, ve	18.52	2.880	3
6	18°29'S	50°45'W	ws	14.42	2.880	2.7
				Total	20.16	19.3

ary, 2017. The sample effort was dependent on the size of the remnants, where larger remnants required greater effort than the smaller ones (Table 1).

The active search was performed in linear transections inside the patches and along the edges. Each remnant had two transects, one inside and the other along the edge. The transects inside the remnants had a minimum distance of at least 200 m from the edge, while transections along the edge were made on the borders of the remnants, in the transition between the remnant and the matrix, with the size of transects varying according to the size of each remnant. We performed active searches, two for each transect, and one at the beginning and one at the end of the campaign. Therefore, the size of the transect in each remnant varied. We did field incursions recording species presence/absence and set seven camera traps on the trunks of trees at 40 cm in height along pre-existing mammalian trails, with a distance of at least 1km between each camera trap. These trails were located 300 m from the edge of the remnants. We left them operating 24h a day throughout the three months of sampling. Cameras were programmed to take three consecutive photos when triggered, with a 30 s lock period immediately afterwards. The largest remnant (remnant 1, see Figure 1, Table 1) had two cameras, the other remnants had only one camera. Our sampling effort was 19.3 km of active search, along with 2,016 hours of photographic traps.

Images and tracks were identified based on Lima-Borges and Tomás (2004), and Hannibal *et al.* (2015b). Cervids from the genus *Mazama* were only identified at the species level when recorded by camera traps, due to their track similarity (Lima-Borges & Tomás, 2004). The taxonomic classification followed the one set by Paglia *et al.* (2012).

Data analysis

We estimated species richness analysis using 1st order Jackknife with 1000 randomizations (Colwell *et al.* 2004), where each camera trap and active search per day were considered as one sample unit. The number of days in which the cameras were active were added to the active search effort. We quantified the frequency of records of medium- and large-sized mammals from the total records of each species and

divided this number by the total records for each remnant. The registers were considered independent of each other with an interval of 30 min. To obtain the average frequency of the species from the six remnants, we added the frequency of each species in the six remnants and divided this by the number of sampled remnants. We classified species according to the occurrence status as common, frequent or rare. The species was classified as common (C) when the mean frequency of the species was >6, frequent (F) when the mean was <6 and >1 and as rare (R) when the mean was <1. Additionally, we described the activity periods of those species classified as common according to the occurrence status. For this, we used only camera trap images, as the time the image was taken is necessary. Therefore, each camera image was considered as independent.

Results

We recorded 23 species of medium- and large-sized mammals, distributed in the orders Carnivora (9 species), Cingulata (3 species), Rodentia (3 species), Artiodactyla (2 species), Pilosa (2 species), Perissodactyla (1 species), Primates (1 species)

Figure 2. Photographic records, footprints and burrows of medium and large sized mammals from six remnants of southern Cerrado, Brazil **A** *Priodontes maximus* **B** *Chrysocyon brachyurus* **C** *Leopardus pardalis* **D** *Tapirus terrestris* **E** *Pecari tajacu* **F** *Eira Barbara*.

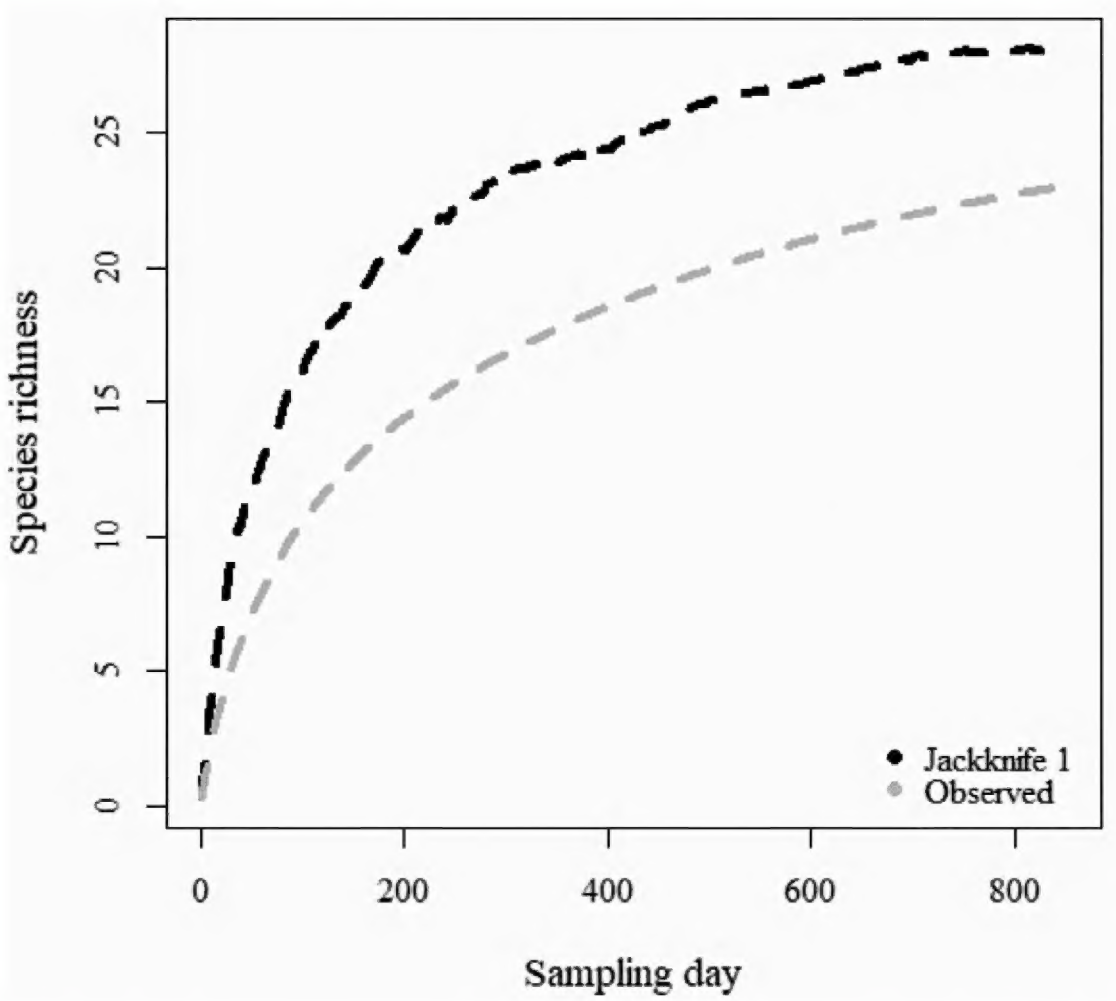

Figure 3. Species accumulation and rarefaction curves (jackknife) for medium and large sized mammals in six remnants of southern Cerrado, Brazil.

and Didelphimorphia (1 species) (Table 2, Figure 2). Ten species were recorded exclusively by camera trap, while four species were recorded exclusively by active search (Table 2), therefore reinforcing the importance of working with complementary methodologies. The species accumulation curves demonstrated an asymptote (Jackknife 1= 8.71± 5.0 species, (see Figure 3 for the remnants), thus suggesting that the sampling effort was enough to inventory the current diversity of medium- and large-sized mammals in the area of study.

Seven species are classified as Vulnerable in national or international red lists (ICMBio, 2014; IUCN, 2017; see Table 2), such as two species of puma, namely *Puma concolor* (Linnaeus, 1771) and *Puma yagouaroundi* (É. Geoffroy, 1803), and the Brazilian tapir *Tapirus terrestris* (Linnaeus, 1758). In addition, *Dasyprocta azarae* (Lichtenstein, 1823) is Data Deficient (IUCN, 2017). In general, these species did not present a preference for some remnants, occurring in all remnants (Table 2).

In total, five species were classified as common according to the frequency of record, including for example *Tapirus terrestris* and *Cerdocyon thous* (Linnaeus, 1766). Eight species were classified as frequent, such as *Mazama gouazoubira* (G. Fischer, 1814) and *Dasyprocta azarae*. Finally, ten species were classified as rare, such as *Puma yagouaroundi* and *Priodontes maximus* (Kerr, 1792) (Table 3).

Regarding their pattern of activity, *Myrmecophaga tridactyla* (Linnaeus1758) and *Dasypus novemcinctus* (Linnaeus, 1758) were classified as twilight and noc-

Table 2. Species list of medium and large-sized mammals from the six remnants from southern Cerrado, in Brazil. National threat category according ICMBIO (2014), and international threat category according to IUCN (2016): data deficient (DD), near threatened (NT) and vulnerable (VU). Methods: burrow (B), camera trap (C), direct observation (D), and tracks (T) and vocalization (V).

ORDEM/Family/*Species*	Remnants	ICMbio	IUCN	Methods
DIDELPHIMORPHIA – Didelphidae				
Didelphis albiventris (Lund 1840)	5, 6			C
PILOSA – Myrmecophagidae				
Myrmecophaga tridactyla (Linnaeus 1758)	1, 3, 6	VU	VU	C
Tamandua tetradactyla (Linnaeus 1758)	1, 3, 6			C
CINGULATA – Dasypodidae				
Dasypus novemcinctus (Linnaeus 1758)	1-6			C,T,B
Euphractus sexcinctus (Linnaeus 1758)	2			T
Priodontes maximus (Kerr 1792)	1	VU	VU	C,B
Cabassous unicinctus (Linnaeus 1758)	2			
PRIMATES – Cebidae				
Sapajus libidinosus (Spix 1823)	1, 4			C,V
CARNIVORA – Felidae				
Leopardus pardalis (Linnaeus 1758)	2			C
Puma concolor (Linnaeus, 1771)	1	VU		C,T
Puma yagouaroundi (É. Geoffroy 1803)	5	VU		C
CARNIVORA – Canidae				
Cerdocyon thous (Linnaeus 1766)	2, 3			C,T
Chrysocyon brachyurus (Illiger 1815)	2	VU	NT	T
Lycalopex vetulus (Lund 1842)	1, 2	VU		T
CARNIVORA – Mustelidae				
Eira barbara (Linnaeus 1758)	1, 3, 5			C,T
Lontra longicaudis (Olfers 1818)	4			T
CARNIVORA – Procyonidae				
Procyon cancrivorus (G. Cuvier 1798)	2, 5			C,T
PERISSODACTYLA – Tapiridae				
Tapirus terrestris (Linnaeus 1758)	1-5	VU	VU	C,T
ARTIODACTYLA – Tayassuidae				
Pecari tajacu (Linnaeus 1758)	1, 2, 6			C,T
ARTIODACTYLA – Cervidae				
Mazama gouazoubira (G. Fischer 1814)	1, 2			C
RODENTIA – Caviidae				
Hydrochoerus hydrochaeris (Linnaeus 1766)	4, 5			T
RODENTIA – Dasyproctidae				
Dasyprocta azarae (Lichtenstein 1823)	1, 2		DD	C,T
RODENTIA – Cuniculidae				
Cuniculus paca (Linnaeus 1766)	4, 5			C,T

turnal. *Tapirus terrestris* was active during the day, but with a nocturnal preference. *Cerdocyon thous* was active during the day and the night, but with a twilight preference. *Cuniculus paca* (Linnaeus, 1766) was strictly nocturnal (Figure 4).

Table 3. Record frequency for each species in percentage (%), and status the occurrence: C (common), F (frequent) and R (rare), for six remnants from southern Cerrado, in Brazil.

Species	Mean %	Status the occurrence
Dasypus novemcinctus	34.94	C
Tapirus terrestris	16.91	C
Myrmecophaga tridactyla	10.07	C
Cuniculus paca	9.61	C
Cerdocyon thous	6.44	C
Pecari tajacu	4.34	F
Tamandua tetradactyla	4.09	F
Dasyprocta azarae	2.54	F
Mazama gouazoubira	1.97	F
Didelphis albiventris	1.77	F
Eira barbara	1.04	F
Hydrochoerus hydrochaeris	1.03	F
Sapajus libidinosus	1.0	F
Lontra longicaudis	0.79	R
Puma yagouaroundi	0.73	R
Procyon cancrivorus	0.53	R
Leopardus pardalis	0.41	R
Lycalopex vetulus	0.41	R
Cabassous unicinctus	0.28	R
Chrysocyon brachyurus	0.28	R
Euphractus sexcinctus	0.28	R
Puma concolor	0.25	R
Priodontes maximus	0.12	R

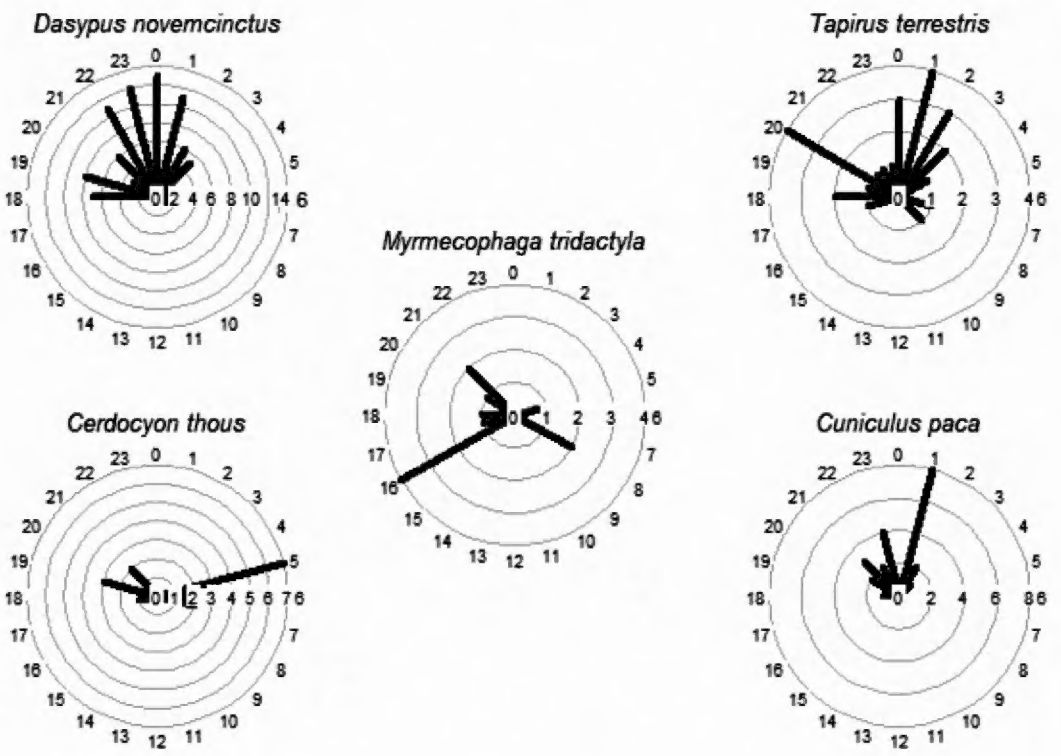

Figure 4. Activity period for common species of medium and large sized mammals (*Dasypus novemcinctus*, *Tapirus terrestris*, *Cerdocyon thous, Cuniculus paca* and *Myrmecophaga tridactyla*) for six remnants of southern Cerrado, Brazil. The central axis indicates the number of photographs, and the bars indicate the number of records for each hour of the day (1 to 24 h).

Discussion

The study area preserves 45.1% of all species richness present in the Cerrado biome. The order Carnivora had the highest richness, which was expected since this biome holds the highest diversity of this group in relation to other biomes (Paglia *et al.* 2012). We recorded species that were not inventoried in the previous list of mammals for the southern region of the biome (Hannibal *et al.* 2015), namely *Puma yagouaroundi*, *Priodontes maximus*, *Mazama gouazoubira,* and *Cuniculus paca*. Two of these species (*P. yagouaroundi* and *P. maximus*) are classified as vulnerable on the national or international red lists (ICMbio, 2014; IUCN, 2017). On the other hand, threatened species previously recorded for the region, such as *Panthera onca*, were not found during our study (Rodrigues *et al.* 2002; IUCN, 2017). Therefore, our results support the importance of continued inventory studies, both to reduce knowledge gaps and to identify potential local extinctions.

In fact, although the study region is highly fragmented, it still harbors an expressive fauna of medium- and large-sized mammals, including threatened species. The occurrence of these species from small to large remnants indicates that they are widely distributed throughout the landscape. However, any conservation plan should consider that the presence of these species in small remnants may be only for temporary use of resources (Calaça *et al.* 2010). Thus, conservation strategies should take into account the delimitation of corridors to connect these remnants, thus enabling the effective conservation of the threatened species in the region.

The frequency of occurrence of medium- and large-sized mammal species is more related to biological and ecological characteristics, such as detection degree, habitat use, and home range (Kasper *et al.* 2007), yet it can tell us how often the species move through the remnants. *Myrmecophaga tridactyla, Dasypus novemcinctus, Tapirus terrestris, Cerdocyon thous* were reported as common or with occurrences in several remnants in their surroundings. Their occurrence was expected since they a have large home range, and therefore, can be recorded more frequently (Reis *et al.* 2011; Bernardo & Melo, 2013; Hannibal *et al.* 2015). Other species classified as rare, such as *Chrysocyon brachyurus* (Illiger, 1815), *Euphractus sexcinctus*, *Lontra longicaudis* (Olfers1818), and *Puma concolor*, are cited in other studies as difficult to be found (Hannibal *et al.* 2015a, Kasper *et al.* 2007), especially *L. longicaudis*, which is semi-aquatic.

In general, activity patterns were very similar to other studies investigating mammal species, e.g. *D. novemcinctus*, *T. terrestris, C. thous* and *C. paca* (see Gómez *et al. 2*005; Kasper *et al.* 2007; Norris *et al.* 2010). Habitat fragmentation as well as intrinsic factors, such as body size and related variables (life history, body size), have been indicated as the main factors that may influence activity patterns of medium- and large-sized mammals (Van Schaik & Griffiths, 1996; Norris *et al.* 2010). For instance, mammals with a small body size tend to be nocturnal as an anti-predation strategy (Gómez *et al.* 2005), which is the case of the nocturnal species *D. novemcinctus* and *C. paca* recorded in this study. *Cerdocyon thous* is an

opportunistic predator, thus being active during all periods (Kasper *et al.* 2007). In contrast, large mammals, such *M. tridactyla* and *T. terrestris*, show more variable activity patterns, probably related to the lower predation pressure on these species.

Overall, our study exemplifies the importance of continued inventory studies, especially for the more impacted biomes. The southern portion of the Cerrado, although highly fragmented, still harbors an expressive fauna of medium- and large-sized mammals, including threatened species distributed throughout the entire landscape and without remnant selectivity. However, we emphasize the need to properly plan conservation measures for the region in order to maintain or even increase the potential of these remnants for the dispersal and survival of mammal species.

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Resumo

Mamíferos de médio e grande porte em remanescentes florestais do sul do Cerrado: diversidade e ecologia

Apresentamos um conjunto completo de dados sobre a riqueza de mamíferos de médio e grande porte para o sul do Cerrado. Descrevemos a frequência, status de ocorrência e período de atividade das espécies mais comuns. Em cada remanescente, a comunidade de mamíferos de médio e grande porte foi inventariada através dos seguintes métodos: pegadas, vocalizações, visualizações diretas, tocas e registros por armadilhas fotográficas durante agosto de 2016 a janeiro de 2017. Registramos 23 espécies de médio e grandes mamíferos, das quais sete são ameaçadas. A área de estudo apresentou um grande potencial, onde registramos 45.1% de todas as espécies de médio e grandes mamíferos ocorrentes no Cerrado. *Myrmecophaga tridactyla, Dasypus novemcinctus, Tapirus terrestris, Cerdocyon thous* e *Cuniculus paca* foram classificadas como comuns, o que era esperado, uma vez que possuem extensa área de vida, podendo, portanto, serem registradas mais frequentemente. Espécies com grande massa corporal, tais como *T. terrestris, M. tridactyla* e *C. thous*, também foram os que apresentaram maior variação no período de atividade, ocorrendo no período noturno e diurno. Portanto, nosso estudo destaca que esta área, embora fragmentada, ainda mantém uma expressiva fauna de mamíferos de médio e grande porte, incluindo espécies ameaçadas.

Palavras-chave

Espécies ameaçadas, frequência, inventory, *Puma yagouaroundi*